IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Before the Board of Patent Appeals and Interferences

In re the Application of

Inventor	**:**	**Gary A. Schwartz**
Application No.	**:**	**10/574,184**
Filed	**:**	**March 30, 2006**
For	**:**	**ULTRASONIC VOLUMETRIC IMAGING BY COORDINATION OF ACOUSTIC SAMPLING RESOLUTION, VOLUMETRIC LINE DENSITY, AND VOLUME IMAGING RATE**

APPEAL BRIEF

On Appeal from Group Art Unit 3737
Examiner Joseph M. Santos

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I. REAL PARTY IN INTEREST

The real party in interest is Koninklijke Philips Electronics N.V., Eindhoven, The Netherlands by virtue of an assignment recorded March 30, 2006 at reel 017765, frame 0582.

II. RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences.

III. STATUS OF CLAIMS

This application was originally filed with Claims 1-22. Claims 17-22 were canceled. The remaining Claims 1-16 stand finally rejected and are the subject of this appeal.

IV. STATUS OF AMENDMENTS

No amendments or other filings were submitted in response to the rejection mailed August 6, 2010. A notice of appeal was timely filed on November 5, 2010.

V. SUMMARY OF THE CLAIMED SUBJECT MATTER

The subject matter of the claimed invention is an ultrasonic diagnostic imaging system for three-dimensional (3D) scanning and imaging. It is known that when an image area, such as a plane of the body which is to be imaged with a two-dimensional (2D) ultrasound image, is scanned, it is necessary to adequately spatially sample the image plane with a sufficient number of beams which are appropriately spaced to cover the image area. When the beams are too widely spaced apart the image area is not adequately spatially sampled and image artifacts will arise. These spatial aliasing artifacts will manifest themselves as an annoying shimmering of the image. The well established solution to this problem, as done by Seyed-Bolorforosh, is to transmit more beams so as to fill in and sample the spaces between the widely spaced beams.

But when 3D imaging is done, the problem becomes more complex. In 3D imaging the beams are transmitted to scan a volume, not simply a plane. Instead of needing only a hundred or so beams to scan a plane, many hundreds or thousands of beams are needed to scan the volume. This is because a volume does not have simply an azimuth (width) and a depth dimension as does an image plane, it has a third dimension referred to in ultrasound as the elevation dimension. The time

required to fully scan the volume with beams determines the frame rate of the live image display, and with more beams to transmit and receive the frame rate of display can decline to an unacceptable level for live imaging. Hence, when the volume is spatially undersampled, the time-honored solution of filling in the volume with even more transmitted beams will increase the time required to fully scan the volume, causing the frame rate of display to become even worse.

The present invention solves this problem in an elegant way which does not degrade the frame rate. Instead of transmitting more beams, the beamformer of the ultrasound system controls the point spread function of the beams in both azimuth and elevation to adequately spatially sample the volume in both dimensions. As the line density decreases to increase the frame rate of display, for instance, the controlled point spread function increases the beam density profile to adequately spatially sample the volume in both azimuth and elevation. As a result, the frame rate can be increased in 3D imaging without causing artifacts from spatial undersampling.

Independent Claims 1 and 9 are supported by the drawings and specification as seen by reference numerals (#) of the drawings and the specification text (pg., ln) as follows:

1. An ultrasonic diagnostic imaging system for three dimensional scanning comprising:

a two dimensional array transducer {#12; pg. 8, ln 1-6} having a plurality of transducer elements;

a beamformer {#18; pg. 8, ln 6-14; pg. 9, ln 8-25} coupled to the array transducer which causes the transducer to scan a volumetric region with a plurality of transmit beams and to receive echo information in response to transmit beams, the beamformer controlling the point spread functions of beams transmitted and/or received by the beamformer in the azimuth and elevation dimensions;

an image processor {#38; pg. 9, ln 1-2} coupled to the beamformer which produces image signals in response to the echo information; and

a display {#40; pg. 9, ln 2-3} coupled to the image processor,

wherein beams produced by the beamformer exhibit a first point spread function when the volumetric region is scanned with a first line density and a second point spread function when the volumetric region is scanned with a second line density {pg. 2, ln 5-8; pg. 12, ln 9-13}.

9. An ultrasonic diagnostic imaging system for three dimensional scanning comprising:

a two dimensional array transducer {#12; pg. 8, ln 1-6} having a plurality of transducer elements;

a beamformer {#18, #22; pg. 6, ln 22-25; pg. 8, ln 6-14; pg. 9, ln 15-22} coupled to the array transducer which causes the transducer to scan a volumetric region with a plurality of transmit beams and to receive echo information in response to transmit beams, the beamformer controlling the point spread functions of beams transmitted and/or received by the beamformer in the azimuth dimension and the elevation dimension by control of the aperture function of the array transducer;

an image processor {#38; pg. 9, ln 1-2} coupled to the beamformer which produces image signals in response to the echo information; and

a display {#40; pg. 9, ln 2-3} coupled to the image processor,

wherein the beamformer utilizes a first aperture function when the volumetric region is scanned with a first line density and a second aperture function when the volumetric region is scanned with a second line density {pg. 9, ln 20-29}.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

A. Whether Claims 1-9 and 14-15 were correctly rejected under 35 U.S.C. §103(a) as being unpatentable over US Pat. 5,797,846 (Seyed-Bolorforosh et al.) in view of US pat. pub. no. US2002/0045822 (Powers et al.)

B. Whether Claims 10-13 and 16 were correctly rejected under 35 U.S.C. §103(a) as being unpatentable over Seyed-Bolorforosh et al. in view of Powers et al. and further in view of U.S. Pat. 6,551,246 (Ustuner et al.)

VII. ARGUMENT

A. Whether Claims 1-9 and 14-15 were correctly rejected under 35 U.S.C. §103(a) as being unpatentable over US Pat. 5,797,846 (Seyed-Bolorforosh et al.) in view of US pat. pub. no. US2002/0045822 (Powers et al.)

In the first Office action, these claims were rejected as anticipated by the Mine patent. In the final Office action of October, 2009 this rejection was withdrawn and the claims were rejected as unpatentable over the Seyed-Bolorforosh et al. patent. In the most recent Office action these claims were rejected as being unpatentable over Seyed-Bolorforosh et al. and Powers et al. Other than mention of the term "point spread function," it is respectfully submitted that none of the references commend themselves to the present invention.

As the claim preambles state, the present invention is an ultrasound system for 3D imaging. To scan in three dimensions the claims all recite the use of a two dimensional array transducer. Powers et al. was cited for its mention of a two dimensional array but Seyed-Bolorforosh et al. does not describe or discuss the use of a two dimensional array transducer, since Seyed-Bolorforosh et al. are concerned with only 2D imaging and make only passing mention of 3D imaging. Seyed-Bolorforosh et al. uses a one dimensional array transducer as shown by its description of one in column 1, line 16, "a multiplicity of transducers arranged in a line." A

one dimensional array transducer cannot scan in three dimensions and is constrained to scanning in the azimuthal plane of a 2D image. The characteristics of the beams in the elevation dimension are fixed by the geometry of the array and its lens. Thus the array cannot affect or vary any beam characteristics or the point spread function in both the azimuth and elevation dimensions as called for by all of the claims of the present application.

Seyed-Bolorforosh et al. are trying to optimize the beam distribution over a 2D image to obtain the highest frame rate and least acoustic noise while limiting spatial aliasing to an acceptable level. See column 2, lines 24-27. The highest frame rate is obtained by transmitting the fewest number of beams necessary to scan the image plane with adequate spatial sampling. The solution of Seyed-Bolorforosh et al. to achieving a high frame rate is to determine how many beams are needed in different areas of their sector image field as indicated by the F number for each area. A sector image is scanned by transmitting beams at different angles across the sector. The beams will be closely spaced at the top near the transducer, and will diverge and be more widely spaced apart at the deeper depths. Their solution to the spaces between beams at deeper depths is to fill in the spaces between the widely separated beams with additional beams at the deeper depths. See column 4, lines 32-47.

This, of course, reduces the frame rate, a situation they hoped to avoid. An implementation of the present invention would solve this problem, not by transmitting more beams, but by using a relaxed, broader point spread function for the deeper depths, thereby insonifying the full area with the same number of beams and adequately scanning the region without reducing the frame rate. But since Seyed-Bolorforosh et al. do not control the point spread function of their beams, their only solution can be to fill in the spaces between widely spaced beams with additional beams. Seyed-Bolorforosh et al. similarly recognize that the F number increases at the lateral sides of a sector image field due to the steeper angle of the beams. Recognizing that clinicians always position the anatomy of interest in the center of the image, Seyed-Bolorforosh et al. decrease the number of beams at the lateral sides, tolerating the resultant aliasing artifacts at the sides. An implementation of the present invention would accomplish this with a tighter, more narrow point spread function at the center and a broader, more relaxed point spread function at the lateral sides, thereby adequately spatially sampling both regions with the same number of beams without aliasing artifacts.

The solution of Seyed-Bolorforosh et al. to the aliasing artifact problem is two-fold as described from the bottom of column 5 to the middle of column 6. First, it is to use different numbers of beams in

different azimuthal segments of the image. The aliasing artifact characteristic of each segment will thus be different, so instead of seeing a continuous scintillating pattern, the aliasing pattern will vary from segment to segment and not be a more distractive, regularly repeating pattern across the image. Their second approach is to control the display dynamic range level of the system. As the artifact level increases with the use of fewer, more widely spaced beams, the display dynamic range is made larger. An implementation of the present invention needs neither of these solutions, as it addresses the problem by point spread function control, not by artifact pattern segmentation or display dynamic range control.

Furthermore, Claim 1 recites that the point spread function control is produced by the beamformer exhibiting a first point spread function when a volumetric region is scanned with a first line density and a second point spread function when the volumetric region is scanned with a second line density. Claim 9 recites that point spread function control is produced by use of a first aperture function when the volumetric region is scanned with a first line density and a second aperture function when the volumetric region is scanned with a second line density. Neither of these limitations are shown or suggested by Seyed-Bolorforosh et al. or Powers et al. And since Seyed-Bolorforosh et al. are concerned with only 2D, not

volumetric, imaging (note the reference to lateral point spread function), their embodiments cannot do volumetric scanning in both azimuth and elevation in any event.

The Examiner says that it would have been obvious to one skilled in the art to fire two different rays with different line densities. This statement is incorrect, as rays do not have line densities. Rather, it is the ray-to-ray spacing that defines the line density. The Examiner next says that it would be obvious to overlap the rays. This is also incorrect, as overlapping rays would result in scanning of the same areas twice, with two different rays, which needlessly would result in more rays being needed to scan an area and a consequent reduction in frame rate, contrary to the objective desired by Seyed-Bolorforosh et al. Furthermore, the Examiner says, it would have been obvious that, had Seyed-Bolorforosh et al. scanned a volumetric area in azimuth and the longitudinal dimension (the reference to longitudinal probably meaning elevation), the invention of Seyed-Bolorforosh et al. would scan a volumetric region in both symmetrical/asymmetrical azimuth and elevation dimensions. There is no basis for this statement in Seyed-Bolorforosh et al. as Seyed-Bolorforosh et al. use a one dimensional array which, be definition, has no beam control in the elevation dimension; the elevation beam characteristic is fixed by the lens of the probe. As previously stated, the

only solution to rapid scanning that Seyed-Bolorforosh et al. suggest is to add more beams when the beam spacing become excessive, the only solution available when there is no control of the point spread function.

The dependent claims recite additional limitations not shown or suggested by Seyed-Bolorforosh et al. or Powers et al. For instance, Claim 3 recites the use of narrower and broader beam profiles, Claim 4 recites the overlap of adjacent beams at substantially the same intensity levels, Claims 5-6 and 14-15 recite common satisfaction of the Nyquist criterion, Claim 7 recites the use of a point spread function which is symmetrical in both azimuth and elevation, and Claim 8 recites the use of a point spread function which is asymmetrical in azimuth and elevation. It is respectfully submitted that these dependent claims are patentable over Seyed-Bolorforosh et al. for these additional reasons.

For all of these reasons it is respectfully submitted that Claims 1-9 and 14-15 are patentable over Seyed-Bolorforosh et al. and Powers et al.

B. Whether Claims 10-13 and 16 were correctly rejected under 35 U.S.C. §103(a) as being unpatentable over Seyed-Bolorforosh et al. in view of Powers et al. and further in view of U.S. Pat. 6,551,246 (Ustuner et al.)

Ustuner et al., like Seyed-Bolorforosh et al., confine themselves to 2D imaging and use a one dimensional array transducer 16 as seen in their Figs. 1 and 2(a)-2(c). They are imaging a 2D image plane by a

combination of what are known as synthetic focus and spatial compounding. Synthetic focus is a technique which, instead of scanning lines of the image field with focused beams, transmits a plurality of ultrasound waves which each insonify the entire image field. Thus, echoes can be received from every point in the image field in response to each transmit wave. The transmit characteristics are varied from one transmit event to another, as by using different transducer elements or groups of elements for each transmit event. After all the transmit events have been done and all the returning echoes collected, signals returned from the same image point are combined to produce the image signal for that point. The technique is called synthetic focus because the combined signal synthesized by the combining is similar to a focused echo due to the correlation/decorrelation effected by the combining. A basic patent on synthetic focus imaging is U.S. Pat. 4,604,697 (Luthra et al.) Ustuner et al. transmit two unfocused plane waves, enabling synthetic focus to be performed in the triangular area R where their beams overlap (Fig. 2(c)).

Additionally, Ustuner et al. transmit their two plane waves at different angles, $+\theta$ and $-\theta$ as shown in Figs. 2(a) and 2(b). Each point in the triangular area is thus interrogated by waves from different "look" directions. When echoes from a point which were acquired from different look directions are combined, speckle noise will be reduced by

the square root of N, where N is the number of look directions, a phenomenon known as spatial compounding. See the first column of U.S. Pat. 6,210,328 (Robinson et al.) Ustuner et al. demonstrate this effect in Figs. 20-22. These plots are said to be simulated point spread functions (they do not say what the point spread functions are), but actually they are illustrations of the spatial echo response of their system in the z (depth) and x (azimuth) directions for right-steered (+θ) and left-steered (-θ) plane waves. (Point spread function illustrations have an amplitude or intensity component as shown by the drawings of the present application.) In the response characteristic of Fig. 20, there is a large center spot which is the main lobe response, surrounded by many smaller spots of echoes from the side lobes of the right-steered plane wave beam pattern. Fig. 21 is similar for the left-steered plane wave, but it can be seen that the smaller spot echoes from the side lobes are differently arranged. When these two patterns are combined the large main lobe echoes will additively combine, whereas the uncorrelated side lobe responses will not additively combine, resulting in a reduction of the side lobe noise by the square root of two, as illustrated by Fig. 22. Contrary to the Examiner's understanding, an apodization parameter will not vary based on the beam angle. The same apodization can be used to produce a beam or steered wave of any angle, which is what Ustuner et

al. do. Like Seyed-Bolorforosh et al., this all has nothing to do with the present invention. Like Seyed-Bolorforosh et al., this is not a three dimensional imaging system, there is no two dimensional array transducer, there is no beamformer producing point spread function control in both the azimuth and elevation dimensions, and there is no beamformer utilizing a first aperture function when a volumetric region is scanned with a first line density and a second aperture function when the volumetric region is scanned with a second line density. Powers et al., as previously stated, was cited for its showing of a two dimensional array and does not show or suggest point spread function control. For all of these reasons it is respectfully submitted that Seyed-Bolorforosh et al. and Powers et al. with Ustuner et al. cannot render Claims 10-13 and 16 or their independent Claim 9 unpatentable.

VIII. CONCLUSION

Based on the law and the facts, it is respectfully submitted that Claims 1-9 and 14-15 are patentable over Seyed-Bolorforosh et al. and Powers et al., and that Claims 10-13 and 16 are patentable over Seyed-Bolorforosh et al., Powers et al. and Ustuner et al. Accordingly, it is respectfully requested that this Honorable Board reverse the grounds of rejection of Claims 1-16 of this application which were stated in the August 6, 2010 Office action being appealed.

Respectfully submitted,

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APPENDIX A: CLAIMS APPENDIX

The following Claims 1-16 are the claims involved in this appeal.

1. (previously presented) An ultrasonic diagnostic imaging system for three dimensional scanning comprising:

a two dimensional array transducer having a plurality of transducer elements;

a beamformer coupled to the array transducer which causes the transducer to scan a volumetric region with a plurality of transmit beams and to receive echo information in response to transmit beams, the beamformer controlling the point spread functions of beams transmitted and/or received by the beamformer in the azimuth and elevation dimensions;

an image processor coupled to the beamformer which produces image signals in response to the echo information; and

a display coupled to the image processor,

wherein beams produced by the beamformer exhibit a first point spread function when the volumetric region is scanned with a first line density and a second point spread function when the volumetric region is scanned with a second line density.

2. (original) The ultrasonic diagnostic imaging system of Claim 1, wherein the point spread function comprises the two-way spatial response at a focal region of pulse-echo spatial sampling of the volumetric region.

3. (original) The ultrasonic diagnostic imaging system of Claim 1, wherein the transmit beams exhibit a relatively narrower beam profile at the focus when scanning the volumetric region with a first line

density, and the transmit beams exhibit a relatively broader beam profile at the focus when scanning the volumetric region with a second line density which is less than the first line density.

4. (original) The ultrasonic diagnostic imaging system of Claim 3, wherein adjacent beams overlap at substantially the same intensity levels when scanning the volumetric region with the first and second line densities.

5. (original) The ultrasonic diagnostic imaging system of Claim 4, wherein the transmit beams satisfy the Nyquist criterion for spatial sampling of the volumetric region to substantially the same degree.

6. (original) The ultrasonic diagnostic imaging system of Claim 1, wherein the point spread functions satisfy the Nyquist criterion for spatial sampling of the volumetric region to substantially the same degree.

7. (previously presented) The ultrasonic diagnostic imaging system of Claim 1, wherein the beam point spread function exhibits both an azimuth dimension and an elevation dimension;

wherein point spread function is symmetrical in both the azimuth and elevation dimensions.

8. (previously presented) The ultrasonic diagnostic imaging system of Claim 1, wherein the beam point spread function exhibits both an azimuth dimension and an elevation dimension;

wherein point spread function is asymmetrical in the azimuth and elevation dimensions.

9. (previously presented) An ultrasonic diagnostic imaging system for three dimensional scanning comprising:

a two dimensional array transducer having a plurality of transducer elements;

a beamformer coupled to the array transducer which causes the transducer to scan a volumetric region with a plurality of transmit beams and to receive echo information in response to transmit beams, the beamformer controlling the point spread functions of beams transmitted and/or received by the beamformer in the azimuth dimension and the elevation dimension by control of the aperture function of the array transducer;

an image processor coupled to the beamformer which produces image signals in response to the echo information; and

a display coupled to the image processor,

wherein the beamformer utilizes a first aperture function when the volumetric region is scanned with a first line density and a second aperture function when the volumetric region is scanned with a second line density.

10. (previously presented) The ultrasonic diagnostic imaging system of Claim 9, wherein the aperture function comprises the combination of the elements used in an active aperture of the array transducer and the apodization function of the elements of the active aperture.

11. (original) The ultrasonic diagnostic imaging system of Claim 10, wherein the apodization function is controlled to match the point spread function to the line spacing when scanning the volumetric region with the first and second line densities.

12. (original) The ultrasonic diagnostic imaging system of Claim 11, wherein the first line density is greater than the second line density; and

wherein the apodization function is controlled to scan an increased depth-of-field when scanning the volumetric region with the second line density.

13. (original) The ultrasonic diagnostic imaging system of Claim 10, wherein the apodization function comprises the relative weighting of signals of the respective elements of the active aperture during a transmission or reception event.

14. (original) The ultrasonic diagnostic imaging system of Claim 9, wherein the first and second aperture functions satisfy the Nyquist criterion for spatial sampling of the volumetric region to substantially the same degree.

15. (original) The ultrasonic diagnostic imaging system of Claim 14, wherein the first and second aperture functions both substantially exactly satisfy the Nyquist criterion for spatial sampling of the volumetric region.

16. (original) The ultrasonic diagnostic imaging system of Claim 10, wherein the scanning beams exhibit a substantially constant angular sampling density; and

wherein the apodization function is varied as a function of beam angle to compensate for transducer acceptance angle effects.

17. - 22. (canceled)

APPENDIX B: EVIDENCE APPENDIX

None. No extrinsic evidence has been submitted in this case.

APPENDIX C: RELATED PROCEEDINGS APPENDIX

None. There are no related proceedings.